A COMPUTER SOLVED SCHEDULING PROBLEM

DIRECTED STUDY

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MASTER OF SCIENCE

By

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A COMPUTER SOLVED SCHEDULING PROBLEM

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INTRODUCTION

The purpose of this paper is to illustrate the use of the computer in solving complex real time scheduling problems. This problem involves the airline industry and is concerned with the local scheduling of security personnel to the gate areas for outgoing flights from one terminal at Dallas-Fort Worth airport.

Data is developed from two areas, the flight status board and the personnel of the security company. The program relays to management a personnel schedule for flight operations.

If adequate personnel are not available throughout the work day to perform the operations, the program will relay the names of those people to call for overtime in the correct sequence to comply with union regulations. Any changes to either the flight status board or the personnel complement will initiate a program run which will update the schedule and give management information to take appropriate action.

The purpose of this type of program is to enhance personnel efficiency and management control over a large group of people while cutting the cost of lower management.

THE PROBLEM

At the present time the company with the scheduling problem is a subsidiary company of a large international airline. The relationship between the two companies is functional. The subsidiary company is tasked to provide the airline with security personnel to screen carry on luggage for concealed weapons that might be used for hi-jack purposes. Also certain aerosol cans must be extracted from the luggage to insure passenger safety in case of a loss in cabin pressure at high altitudes. The objective of the subsidiary company is to provide two qualified people per gate per outgoing flight to screen the carry on luggage for that particular aircraft. At present time this is accomplished by crisis management. A sufficient complement of personnel are assigned daily to cover most of the requirements and a supervisor is responsible for seeing that each outgoing flight has sufficient personnel. The airport terminal for this particular airline is one-half of a mile long with eighteen gates. At present the terminal is divided into four zones with four gates to zone A and D and five gates to B and C. Zone B and C are the most heavily trafficked zones. Each zone has a zone lead who is responsible for scheduling the group of people in his zone assigned to that zone. Employees are assigned to a particular zone every three months. The supervisor can reassign an employee to another zone on a temporary basis one day at a time or as traffic necessitates.

The primary source of data input for the supervisor and the zone lead is the employee master schedule and phone communication to the assistant manager to determine who will be present for that shift's screening tasks. At present the company is operating on a four shift schedule from 0600 to 2330 hours. Shifts begin at 0600, 0700, 1400 and 1500 hours and continue for 8 $\frac{1}{2}$ hours with $\frac{1}{2}$ hour off for lunch and two 15 minute breaks before and after lunch whenever scheduling permits.

The primary source of data within the parent company is the flight status board or a sequential listing on a CRT of daily scheduled flights for a particular day. This status board is updated as information about a particular flight becomes known to the airline or terminal.

Internal scheduling specifications are affected by three agencies outside of the company, the parent company, Teamsters union, and the Federal Aviation Administration. The first most important regulation is by the FAA which states in general terms that two screening personnel and one armed guard must be present for the screening of all luggage and the passengers themselves before boarding all interstate flights. The armed guard is provided by an agency of the government and is not considered a part of the scheduling problem. The parent company has specified that in order to expedite flight departures the pre-screening of luggage should begin 45 minutes prior to each departure. The pre-screening of carry on luggage is done prior to boarding and the luggage is placed in a sterile zone prior to passenger screening. The screening process entails either hand checking of the luggage or an X-Ray check for concealed weapons and passenger screening entails a walk through a magnitometer or metal detector hand wand screen before boarding. The union specifications are merely that a lunch break be given within four hours after working two hours for a given shift. If overtime help is needed, an overtime status board must be signed by an employee prior to the time overtime is needed in order to take advantage of this opportunity. Overtime is granted by the seniority of the people listed on the overtime status board. If no one is listed on the overtime status board, overtime is assigned to the least senior employee not working at the time the overtime is needed.

The problem is to schedule employees to meet the constraints that were mentioned previously.

The manual solution to the problem is to use a hierarchical approach to management from assistant manager in charge of the entire terminal and a supervisor for the screening personnel to direct personnel to crises areas as needed. The lead zone screeners are responsible for scheduling people assigned to their area during their respective shift. If they have a scheduling problem they contact the supervisor who moves people from the other zones. Many times this transition causes confusion and communications between the gates by phone is the primary means to disseminate messages, although a public address system is available as a back up. Another manual solution is to use a set of graphs to determine projected load for a day, but they are just an aide to the previously mentioned manual solution. For both of these solutions, if overtime help is needed the assistant manager makes the decision

based upon his evaluation of a shift's employee complement and based on his current knowledge of the flight schedule. This is very inefficient because although the 18 gates are active only a percentage of the total time, assistant managers have a tendency to be safe rather than sorry. Possibly the prevention of one flight delay could account for the extra cost of overtime. The present system allows for about a 10% absentee rate and can function under a normal flight load.

The outgoing flights follow a Poisson distribution pattern (7) but in using probabilities and statistical distributions we do not arrive at a concrete scheduling solution to solve the daily problem of assigning people to screen outgoing flights. Operations research solutions primarily deal with scheduling in terms of queuing models. This system is considered a multiple-server queuing system. In scheduling police cars for New York City the modeling approach was fine for scheduling patrols and meal times (3). The schedule was set up on a probability distribution of calls. This approach may be of some help in scheduling lunches for screening employees but under emergency conditions lunches can be interrupted and employees assigned since all employees must stay in the terminal and lunches are only one half hour long. Linear programming techniques may be helpful in designing the monthly employee master schedule but in the every day routine operations scheduling, a more direct approach will be necessary.

In the use of computers for solving scheduling problems one area very similar to the present screening problem is that of scheduling nurses in hospitals. In Dr. Jelinek's article (6), this problem was solved through the use of current problems projected to the immediate future, and the daily schedule had a hierarchical approach. Nurses were distributed according to the classifications of patient's needs. The software package is called Pass and was developed by The Medicus Corporation in cooperation with Rush-Presbyterian-St. Luk's Medical Center, Chicago and the Baptist Medical Centers, Birmingham, Alabama. A similar but less comprehensive approach to this same nursing problem has been accomplished by Donald T. Murry (9).

SOLVING THE PROBLEM

The natural data structures in existence are the sequential listing of the flight departures by departure time and a sequential listing of employees by seniority with a shift code and days off. The two lists must be combined in such a manner as to form a schedule with the previously defined constraints. A new file or data structure must be created which can be printed in the form of a schedule with the flight departures and the assigned personnel. Also this structure must be accessed in a manner in which a supervisor can enter an employee name and the program will return a schedule for that employee for his particular shift.

To produce this type of a schedule with the ability to change and update the schedule throughout the work day, it will be necessary in this dynamic environment to use forward linked lists and bidirectional-linked

lists. For storage purposes these linked lists must be stored on a mass storage device, but their linked relationships must be maintained. A language that can utilize bit string processing will be necessary to minimize the storage of the time schedule for employees. It will be necessary to reconstruct at any given time (a time interval for this problem is defined as five minutes) a status of which employees are assigned and which employees are idle. It will also be necessary to add and delete flights throughout the day and release employees for other duties as is necessary. It will also be necessary to allow employees to leave the system throughout the day and the flights covered by these employees must be rescheduled to be covered by other employees. At any given time when insufficient employees are available to cover the required operations, an overtime list should be produced to aide the assistant manager in covering overtime according to union contract demands.

The high level language that utilizes all of the data structures previously mentioned must be general in nature. Linked lists, bit string processing and record input/output can all be processed on the IBM 360 system adequately using PL/I. This language is very versatile and can be utilized affectively using a simulation assignment approach to solving this scheduling problem.

STRUCTURES

The primary approach to the solution of the problem is to set up two area variables in memory and to read into these areas the current flight schedule for the day and the employees scheduled for that particular day. The flight schedule will be read into one area in the form of a forward linked list and have the following structure:

GATE	FLIGHT NO.	DEPARTURE TIME	DESTINATION	ASSIGN ONE	ASSIGN TWO

The forward link list will be linked from earlist outgoing flight in the day sequentially to the last departure of the day. The assignments will be blank initially when the flight status board is read and the program will make these assignments later. The employee file will be read into area two, and this file will be read sequentially by seniority from earliest employee hired to last employee hired. Only the employees working that particular day will be read into the work area. The employee input file will be structured as follows:

DATE OF HIRE	EMPLOYEE NO.	NAME	DAYS OFF	SHIFT CODE

Only the employees that will be working on a particular day will be entered to area two. The internal format for the area two based variables is as follows:

NAME	SHIFT CODE	TIME BIT STRING	ZONE
ASSIGNMENTS 1 through 10		LUNCH	PRIORITY

Each of these two areas will use offsets and pointers to determine which record is next to be processed.

PROCESSING

The initial assignment program will begin by reading the departure time for the first flight and then process through the employee file until it finds an employee who is present 45 minutes prior to that departure time and not assigned. When the employees are entered into area two the time bit string is initialized to zeros. As assignment takes place the time bit string is partially converted to ones representing the time allocated to the flight number. Each bit represents five minutes of time. The shift code indicates at what time the bit string is to begin or what time it is to represent. For example, if the shift code is indicating the employee arrives at 0600 and a flight departure is at 0650 the employee must be assigned to the flight from 0605 to 0650. The bit string would begin at 0600 where the first bit is zero and the next nine bits would be ones. The assignment one area would be assigned the flight number for which the employee is assigned. A priority of one is added to the priority area. At this time the employee's name is entered to the flight assignment one in area two and the search is begun to fill the assignment in area two. This process continues until a flight after 0930 is encountered, at this time a switch is turned on and personnel who are not assigned flights will begin to be assigned a half hour for their meal break beginning at 0800. This switch will remain on until all lunches for this shift are assigned during the processing of further flights. Each time a flight is assigned to an employee his priority is increased by one so that assignments are made to personnel with the lowest priority first. After zones are assigned to an employee on his first flight of the day the zone is not changed, except if there is a need because of heavy traffic or personnel shortages in other zones. If a person is assigned to another zone, he will remain assigned to that zone until the need arises to shift him again. An effort is made to keep from shifting people from zone to zone because of the size of the airport and the actual time that is lost in transiting from one zone to another. As the day progresses and a shift is about to end the problem arises of assigning flights to overlapping shifts. This is actually handled through the priority system although if a flight is assigned to someone that will extend that employee's shift, it will be necessary for him to accept the overtime as an emergency overtime. Emergency overtime is written in the union contract. Oncoming employees will have the lowest priority and will receive the first assignments. During the assignment process if there are insufficient numbers of employees to cover the flights, asterisks are placed in the assignment field of the flight schedule linked-list. Upon completion of the assignment process the entire linked-lists is checked to see if any flights are not assigned and how many people are needed for each shift. People who are called in for overtime will receive at least four hours of overtime regardless of how long they stay. If overtime is needed, it

is better to extend someone on a shift than to call someone in, because this type of overtime can be allocated by 15 minute increments instead of four hour periods. Extended overtime is assigned similar to the call in type of overtime. If the people with the most seniority sign an overtime log they are assigned first to the overtime schedule. After they are assigned and this log is exhausted, mandatory overtime is assigned to those people with the least seniority and again the overtime list is processed in reverse order.

Now that we have the basic assignments we will want two schedules printed. The first schedule will be an assignment of personnel to flights listed in order of flight departure time. It will primarily be a dump of area one. The second schedule will be by employee and shift. It will be a schedule derived from both areas one and two and list the employee, the shift, the flight numbers assigned, a time scale, a representation of the bit string, and a lunch time assignment. Upon completion of both of these schedules when overtime is necessary a reverse seniority list should be printed for personnel who are not working that day.

After the preliminary schedule is printed we will want to be able to change the flight schedule by canceling flights or changing the personnel assignments because of sickness etc. In this type of a dynamic environment it will be necessary to enter and change the schedule throughout the day without creating a complete reassignment of people. To do this it will be necessary to use keywords to identify what you want the system to do. At the beginning of the day you will call the program and type in the first two initials of the day of the week, skip two spaces and type INT-OPS. Later in the day you will call the program and type the first two initials of the day of the week, skip two spaces and then FLT-CHG (flight change) or PER-CHG (personnel change). If the change is a flight change the next card must contain the type of change 'ADD' or 'DROP', skip two spaces, time of day when the flight departs, skip two spaces, flight number, skip two spaces, gate number, skip two spaces, and finally the destination of the flight. If the change is a personnel change the next card must contain the type of change 'ADD' or 'DROP' skip two spaces, time of day, skip two spaces, time employee begins work, skip two spaces, time employee leaves for the day, the shift number the employee will be working, the employee's name. Both schedules are printed after a change and after initialization of operations. A reverse seniority list is printed after initialization of operations of those people who are scheduled off for that particular day.

SOLUTION ANALYSIS

In critiquing the solution it is necessary to determine if this solution first of all covers the objectives of management and handles the demands mentioned earlier by the parent company, the union and the Federal Aviation Administration. The solution does cover these demands and objectives. An area of efficiency which may not be covered well, is the special case of changing shifts in the afternoon when the oncoming shift arrives at 1400 and the off going shift that leaves at 1430 overlap. For instance, a person on the earlier shift should be able to be assigned to start the screening operation on a flight which leaves after 1430 and then at sometime during the half hour from 1400 to 1430 his

duties could be reassigned to someone from the shift beginning at 1400. Under the present solution a particular flight must be assigned and fully screened before the shift leaves. This problem occurs also between 1500 and 1530 hours. Considerable time could be saved, if the system were expanded, by creating more links in the employee area two. You could shorten the paths for finding available employees by having separate links for each shift and separate links for each zone within each shift. This may speed up response time but it would make the program considerably more complex. Another area that may cause problems is extending a flight. It is normally expected that if a flight is delayed temporarily the personnel assigned to that flight will remain on station until the flight departs. Under the proposed solution the flight would be treated as a delete and add, and new personnel would be assigned to cover it. If the flight is just delayed a few minutes it may not be necessary to even enter it into the system.

When initializing operations CPU time on the batch system is about 54 seconds. This time is dependent on the schedule load but only varies by two or three seconds on most normal days of operations. CPU time for flight changes and personnel changes is about 25 seconds and varies by two or three seconds also. All program major paths were tested for accuracy and tested satisfactorily.

PROSPECTIVE USERS

Prospective users should be aware of the peculiarities previously mentioned and should refer to the documentation manual should any specific problems arise. The documentation manual contains the flow charts and file structures necessary for program maintenance. The user should also be aware that a change in a flight time constitutes a delete followed by an add and the same occurs for a zone change in an outgoing flight. Gate changes within the same zone will not change personnel assignments. It should also be noted when a person is called in for overtime and does not begin work at the normal shift start time and will only stay for four hours, this person must be a personnel add and a delete for the shift that the overtime is allocated to. For example, on the 0600 shift if a person is called in for overtime to arrive at 0800 and works to 1200 he will be treated as an add for the 0600 shift but his bit string will show him assigned until 0800 and a delete will show his bit string assigned from 1200 to the end of the 0600 shift. Also for a four hour shift there will be no meal assigned, therefore the meal will be pre-assigned during the deleted period. The program is designed to be used by management and does not need a great deal of instruction to be used as a scheduling tool. As long as the user knows how to call the program and the key words to input, the program will produce the schedule and the schedule changes.

TESTING SCHEME

The testing scheme that will be used to test the program must test the system response time during peak operations. It must return a schedule that utilizes all personnel before overtime is initiated. It must distribute the work load evenly among the active personnel on an average traffic load. During slow periods it is necessary to distribute the work load for each zone. During high absenteeism it is necessary

to indicate needed overtime to allow management enough time to cover projected flights by calling personnel in. Another area of testing is in reaction time. Does the system update the schedule in a reasonable amount of CPU time to make it a feasible solution? How fast can changes be made? The last and most important testing is does it meet the demands of the parent company, the union, and the Federal AViation Administration?

SUMMARY

The objective was to design an automated computer scheduling system that would distribute a work force to numerous tasks over a period of time. This was accomplished through the use of PL/I and a series of data structures, primarily linked - lists and bit strings which were utilized to represent time. The testing system is an IBM 360 and a batch mode of processing. The system is designed in such a manner that it can be used in a real time environment. The changes would primarily be on the flight input side. A program monitor should be initiated to monitor the flight status board which would automatically update the flight portion of the input and initiate a flight change. CRT's could be used in employee break areas for communication to employees by a flashing signal for 15 minutes of that portion of the schedule that has changed. Another area of input could be from the time clock as employees enter and leave the system.

Another possible solution to this scheduling problem is the hierarchical approach presently in use. This system is slow to react and usually inefficient in requiring more personnel than are needed to accomplish the task. The proposed solution allows more central control of the allocation of human resources.

I feel this system could save this company a substantial sum of money per year in cutting personnel expense. It could also operate more efficiently in communicating changed schedules. At present employees are hard to locate from a central management point of view. Communications are primarily through a phone system. The public address system is available but its use is frowned upon by the parent company. This system of scheduling could be used in similar environments to reduce the cost and frustration of real time scheduling. It could also be expanded in airport terminals to include baggage handlers.

FLIGHT ASSIGNMENT SCHEDULE

FLIGHT NO.	DEPARTURE TIME	GATE NO.	DESTINATION	ASSIGNMENT ONE	ASSIGNMENT TWO
237	0830	13	OKC	BETTY KING	OSCAR SMITH

FIGURE #1

PERSONNEL ASSIGNMENT SCHEDULE

EMPLOYEE NAME	ZONE	SHIFT	ASSN ONE	GATE	ASSN TWO	GATE	ASSN THREE	GATE	ASSN FOUR	GATE	ASSN FIVE	GATE	LUNCH
BETTY KING	3	1	745	13									0900
			ASSN SIX	GATE	ASSN SEVEN	GATE	ASSN EIGHT	GATE	ASSN NINE	GATE	ASSN TEN	GATE	

BIT STRING
REPRESENTATION

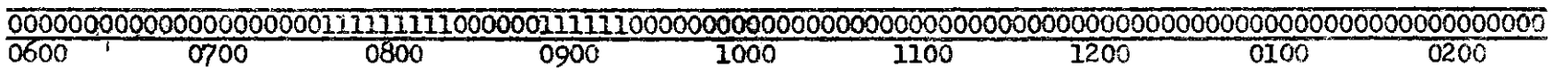
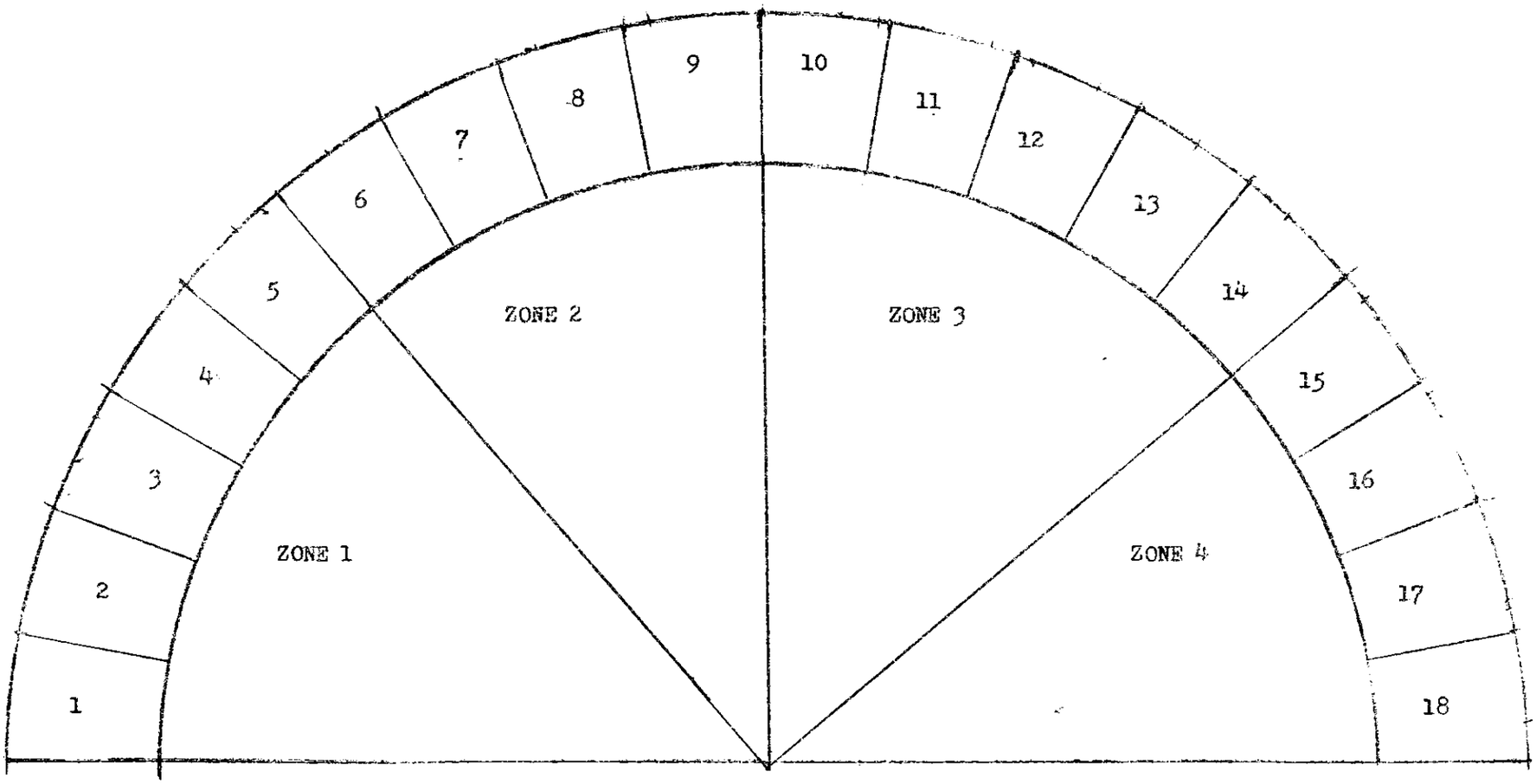


FIGURE #2

AIRPORT TERMINAL BUILDING



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A COMPUTER SOLVED SCHEDULING PROBLEM

DOCUMENTATION MANUAL

By

STANLEY EUGENE MESSINGER

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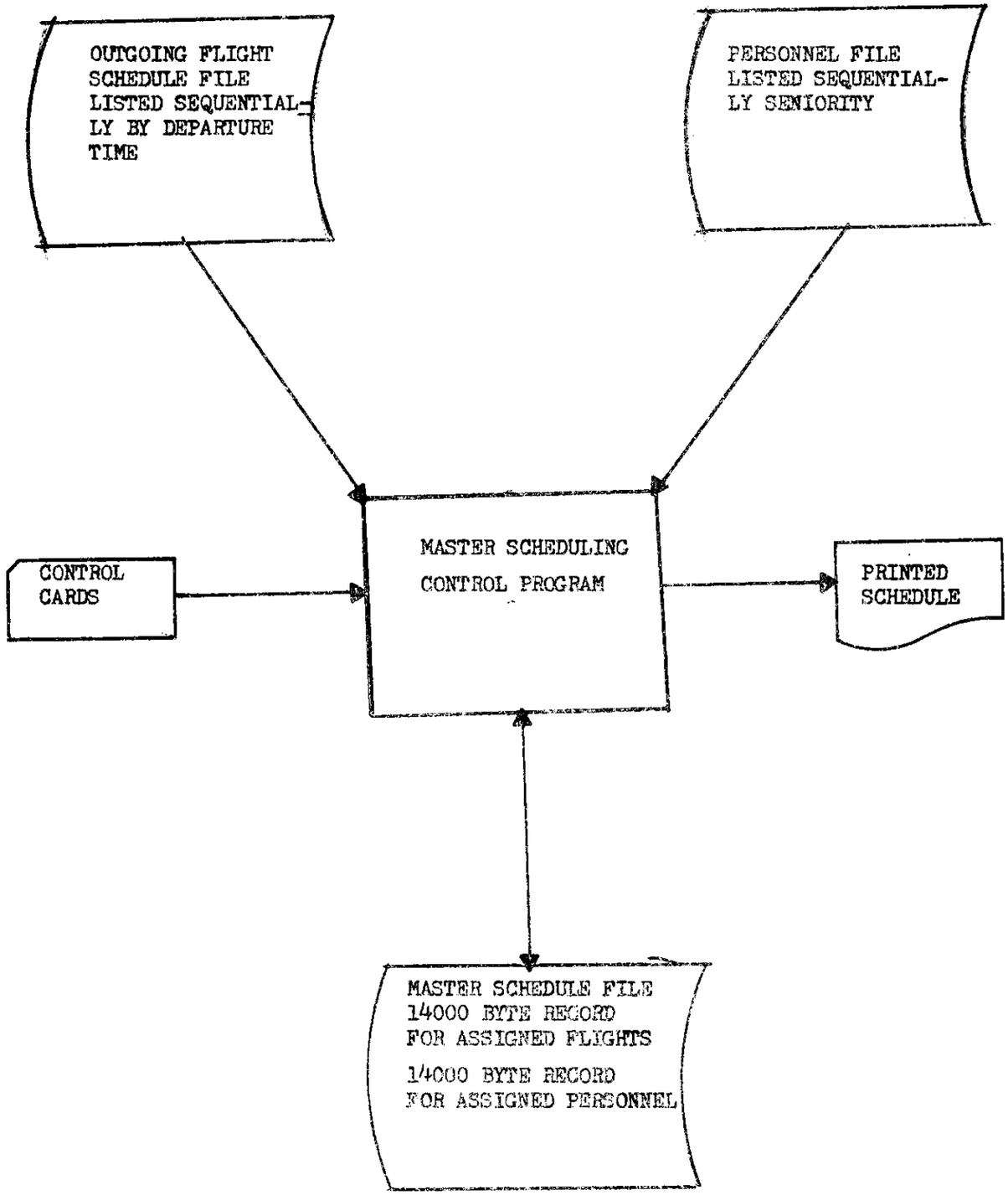
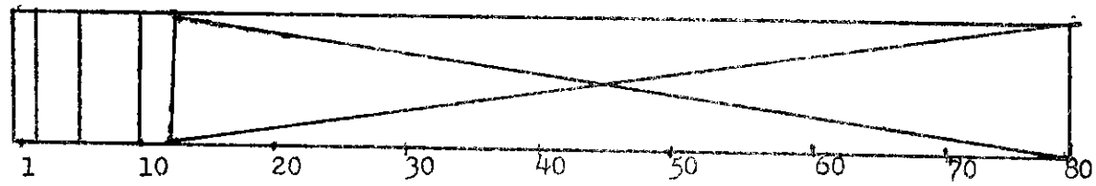
SYSTEM FLOWCHART



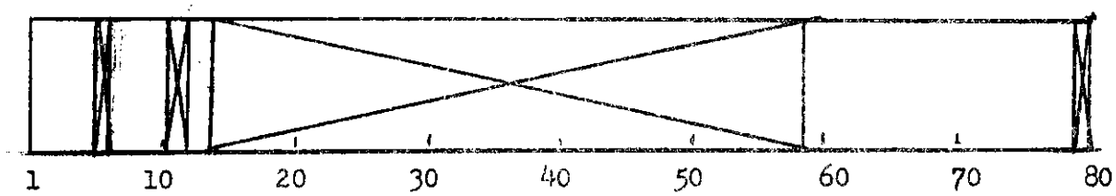
FILES

OUTGOING FLIGHT INPUT FILE



1-2 DEPARTURE GATE NUMBER
3-5 FLIGHT NUMBER
6-9 DEPARTURE TIME
10-12 DESTINATION

PERSONNEL FILE

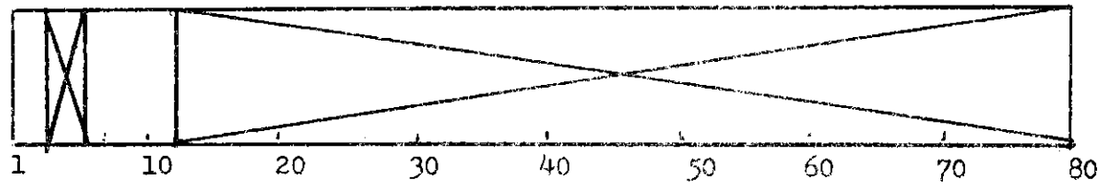


1-5 SENIORITY JULIAN DATE
7-10 FIRST TWO INITIALS OF DAYS OFF
12 PERSON'S NAME

ALL DATA ON THESE TWO FILES ARE UNPACKED EBCDIC CHARACTERS

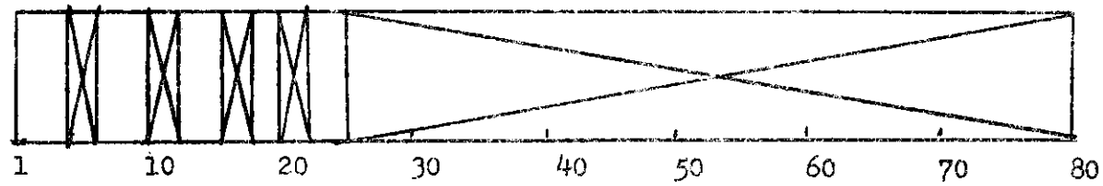
CONTROL CARDS

OPERATIONS CONTROL

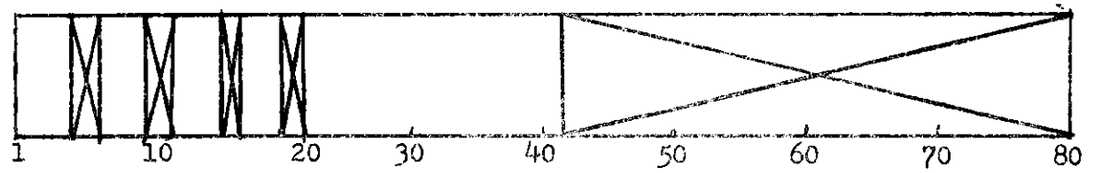


1-2 DAY OF THE WEEK
5-11 OPERATION DESIRED

FLIGHT CONTROL



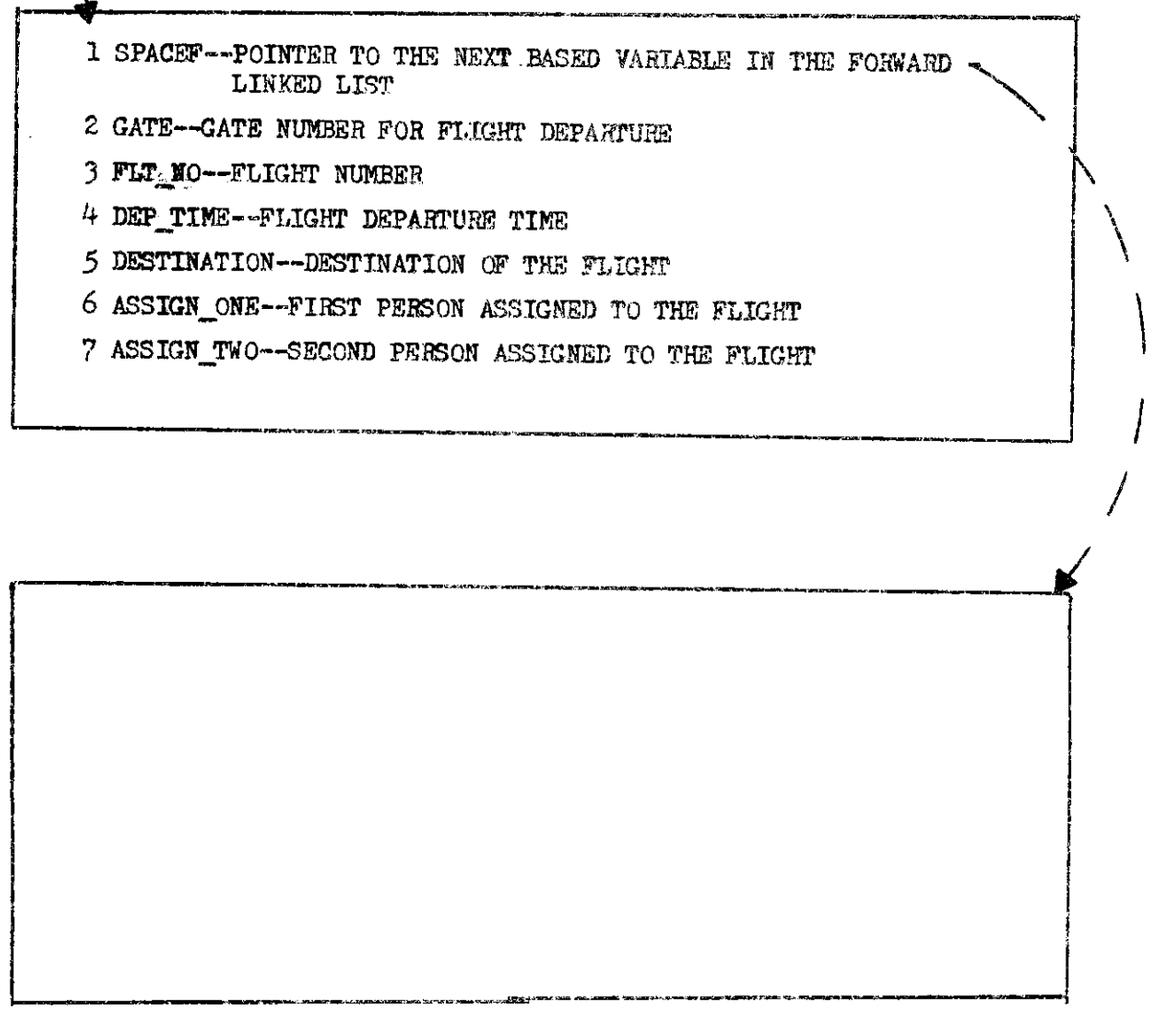
1-4 TYPE OF FLIGHT CHANGE
7-10 TIME OF FLIGHT DEPARTURE
13-15 FLIGHT NUMBER
18-19 GATE NUMBER FOR DEPARTURE
22-24 FLIGHT DESTINATION



1-4 TYPE OF PERSONNEL CHANGE
7-10 TIME OF DAY
13-16 PERSON'S STARTING TIME
19-22 PERSON'S DEPARTURE TIME
25 SHIFT NUMBER
28-47 PERSON'S NAME

FLIGHT SCHEDULE FORWARD LINKED LIST

14000 BYTE RECORD PROCESSED INTERNALLY WITHIN A 13984 BYTE AREA



PERSONNEL SCHEDULE FORWARD LINKED LIST

14000 BYTE RECORD PROCESSED WITHIN A 13984 BYTE AREA

1 SPACEP--POINTER TO NEXT BASED VARIABLE IN FORWARD - LINKED LIST

2 NAME--NAME OF EMPLOYEE

3 ZONE--ZONE WHERE EMPLOYEE IS PRESENTLY ASSIGNED

4 SHIFT--SHIFT EMPLOYEE IS ASSIGNED TO

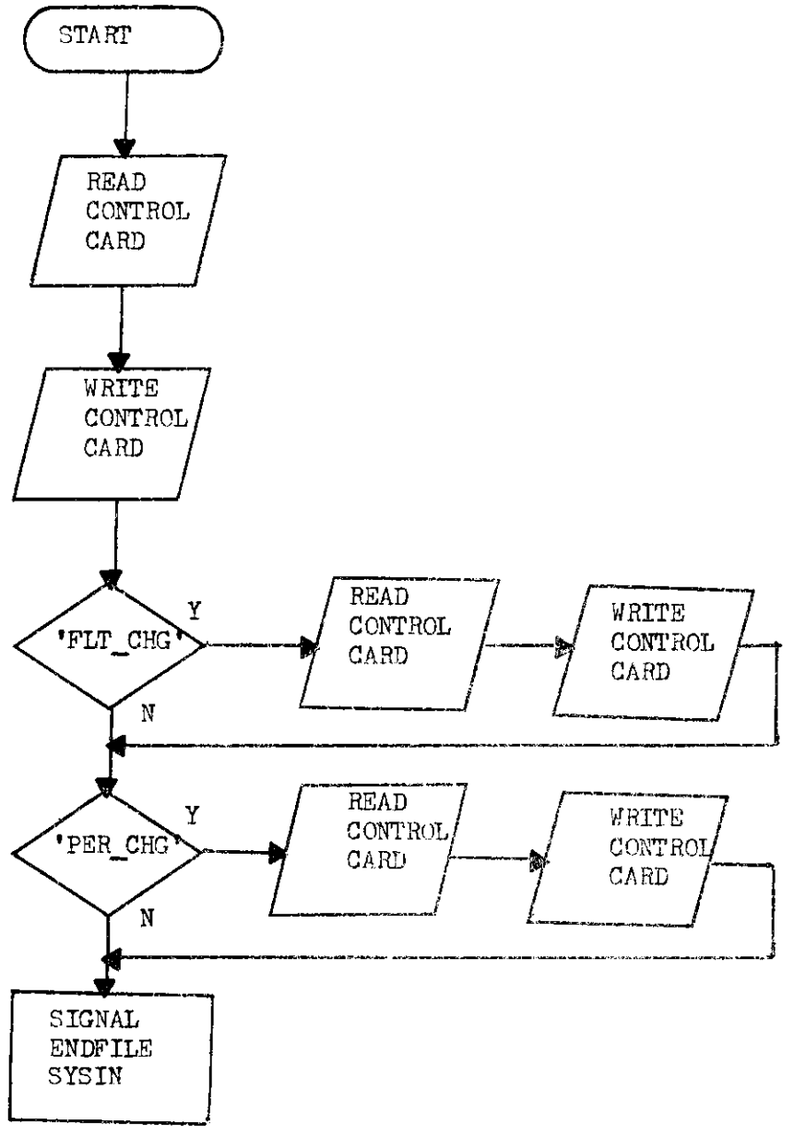
5 ASSGN--AN 11 ELEMENT ARRAY OF GATE STARTING TIMES WITH THE LAST ELEMENT CONTAINING THE LUNCH ASSIGNMENT TIME

6 GATS--A 10 ELEMENT ARRAY OF THE GATE NUMBERS CORRESPONDING TO THE FIRST 10 ELEMENTS IN ASSGN

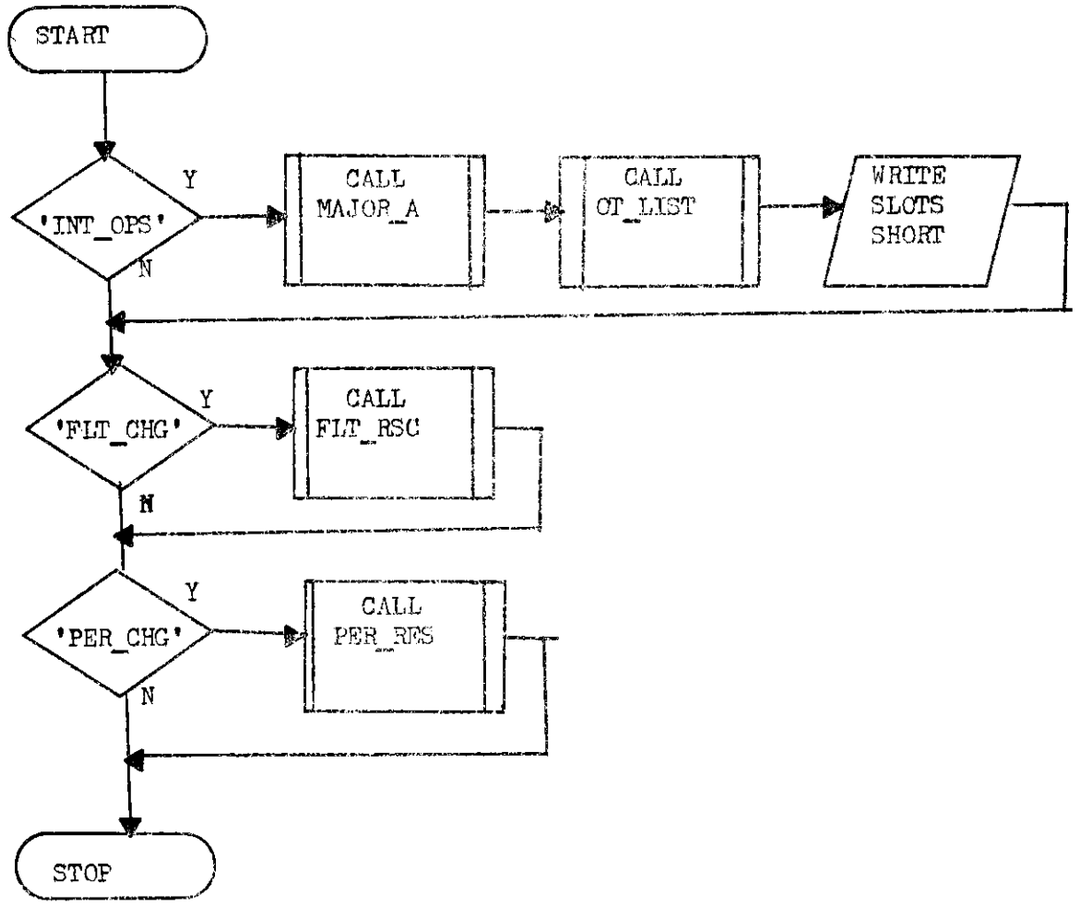
7 PRIORITY--THE TOTAL NUMBER OF FLIGHTS A PERSON HAS WORKED

8 ASSGN_STRG--THIS IS A CHARACTER STRING THAT CONTAINS ZEROS WHEN A PERSON IS UNASSIGNED AND ONES FOR WHEN HE IS ASSIGNED EACH BIT REPRESENTS FIVE MINUTES OF TIME

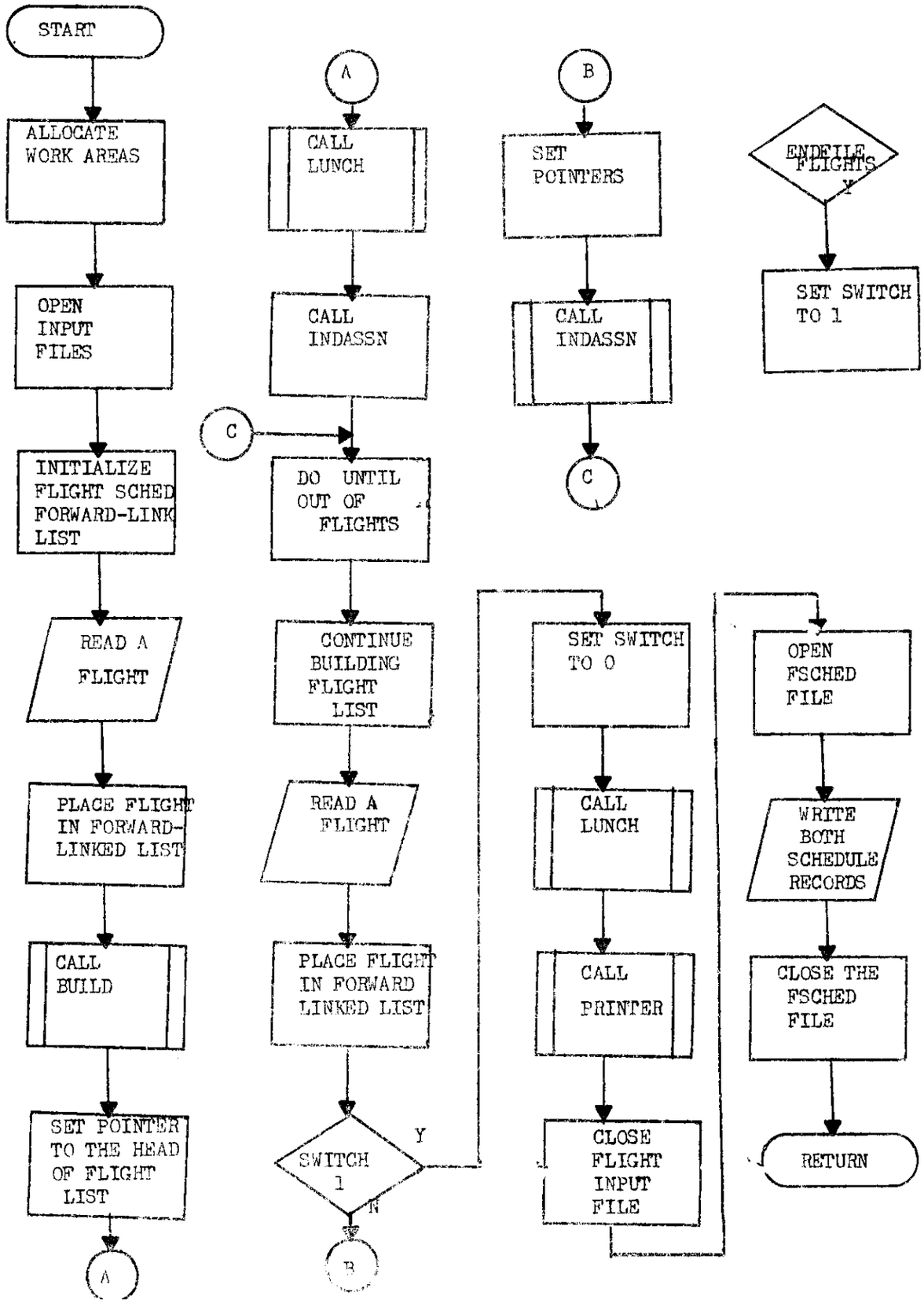
SCHEDUL PROCEDURE



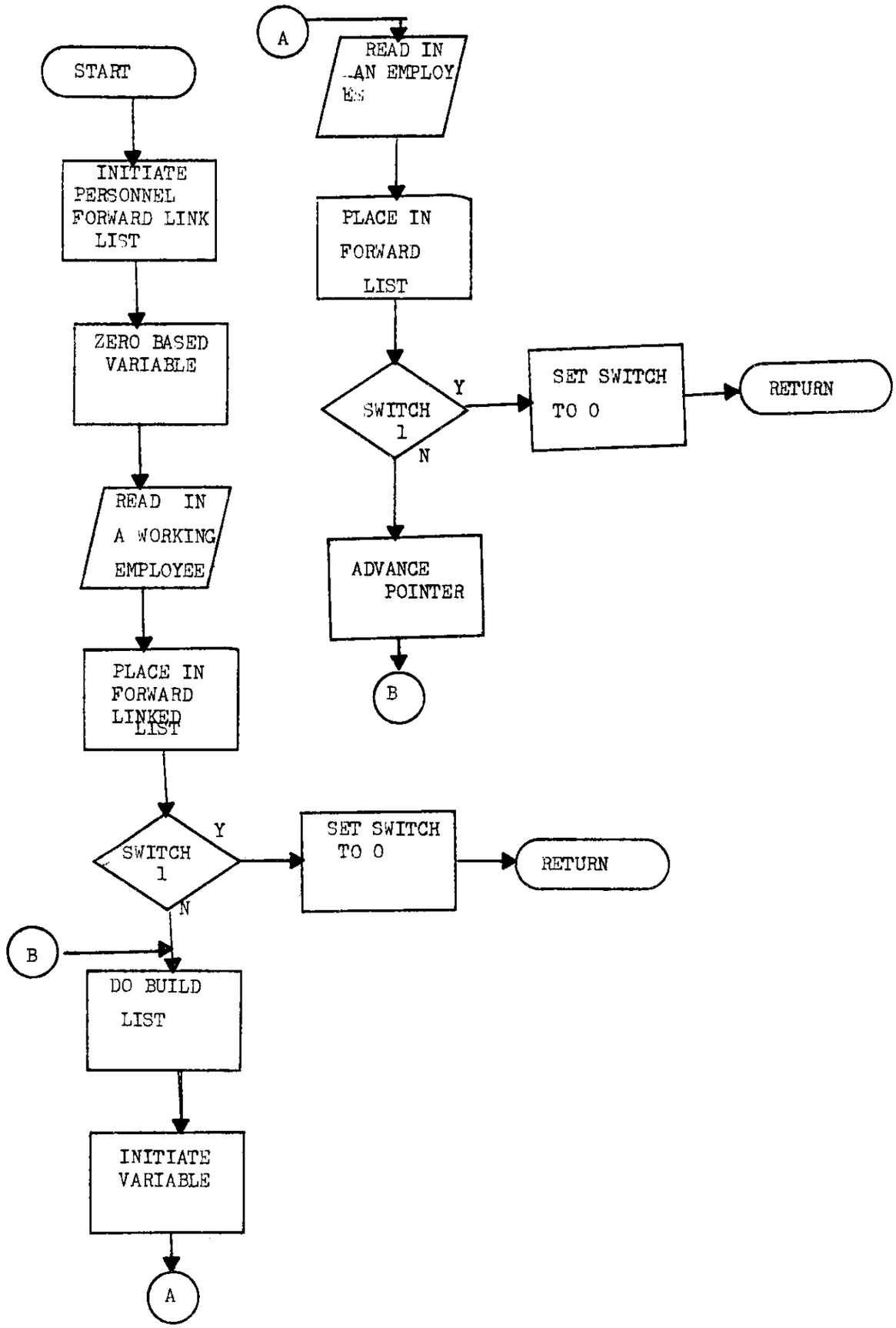
ENDFILE SYSIN BLOCK



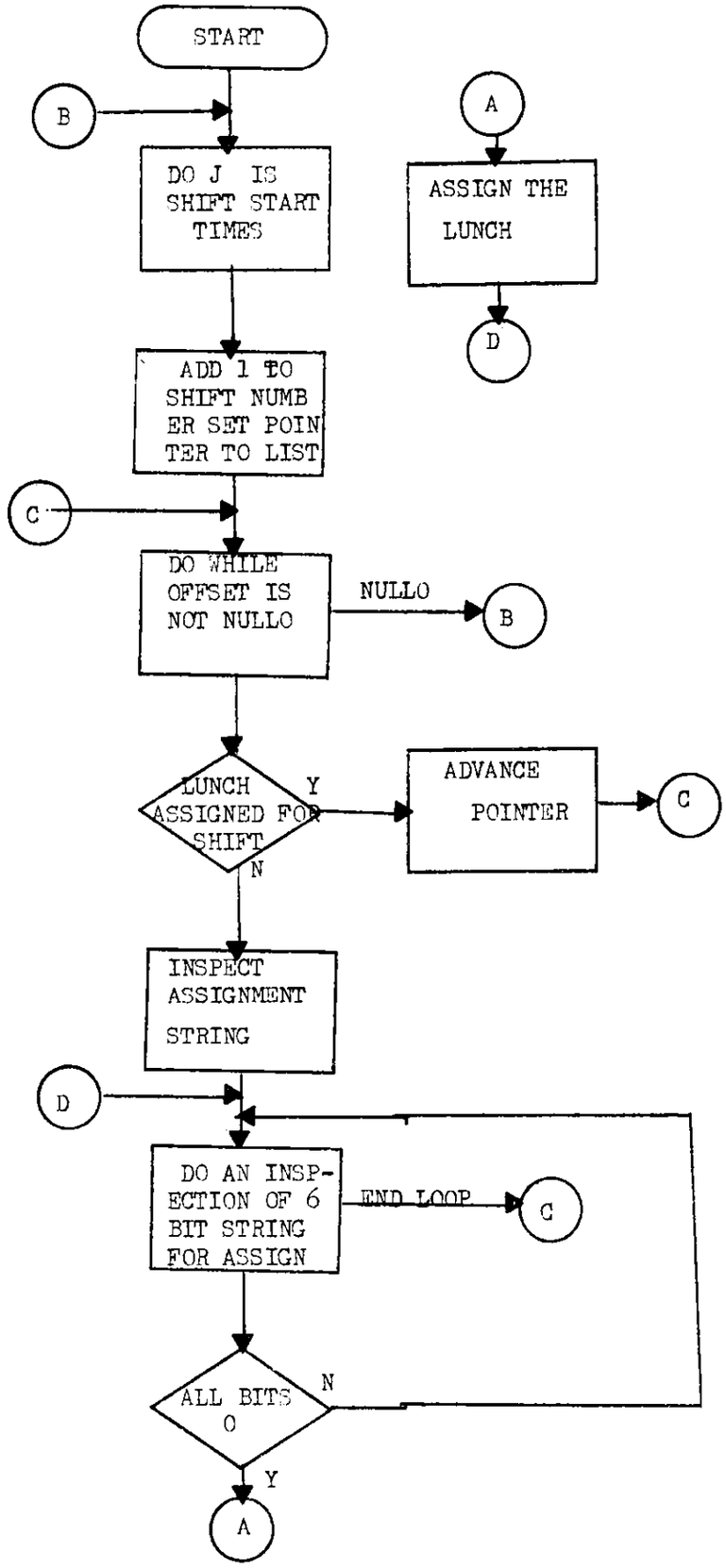
MAJOR_A PROCEDURE



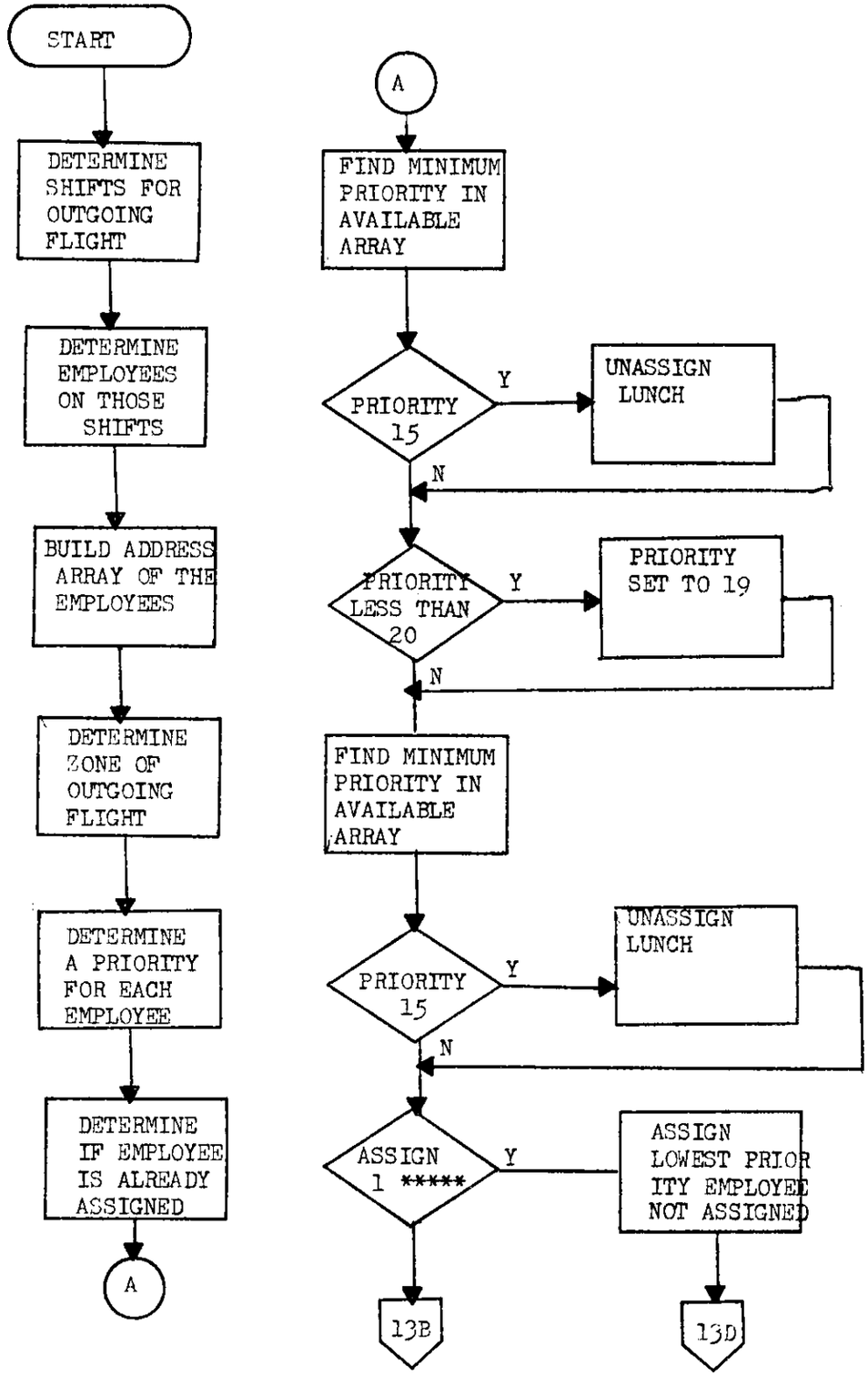
BUILD PROCEDURE

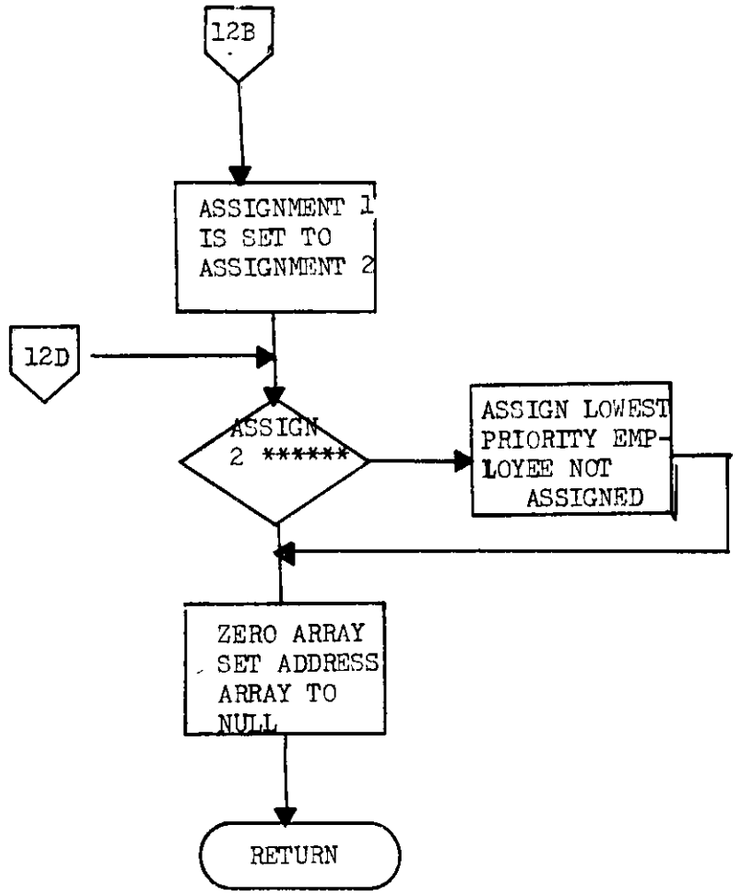


LUNCH PROCEDURE

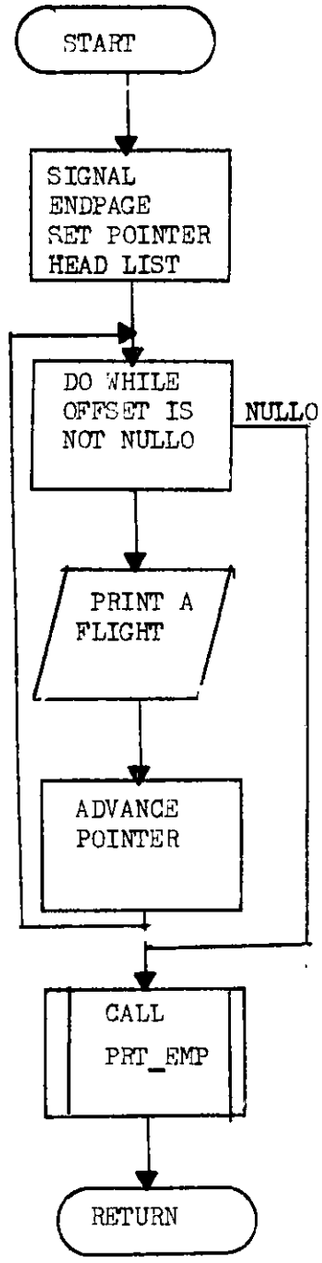


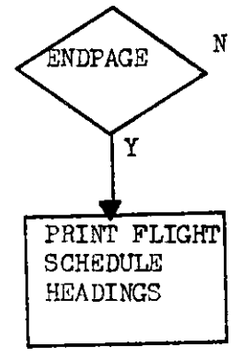
INDASSN PROCEDURE



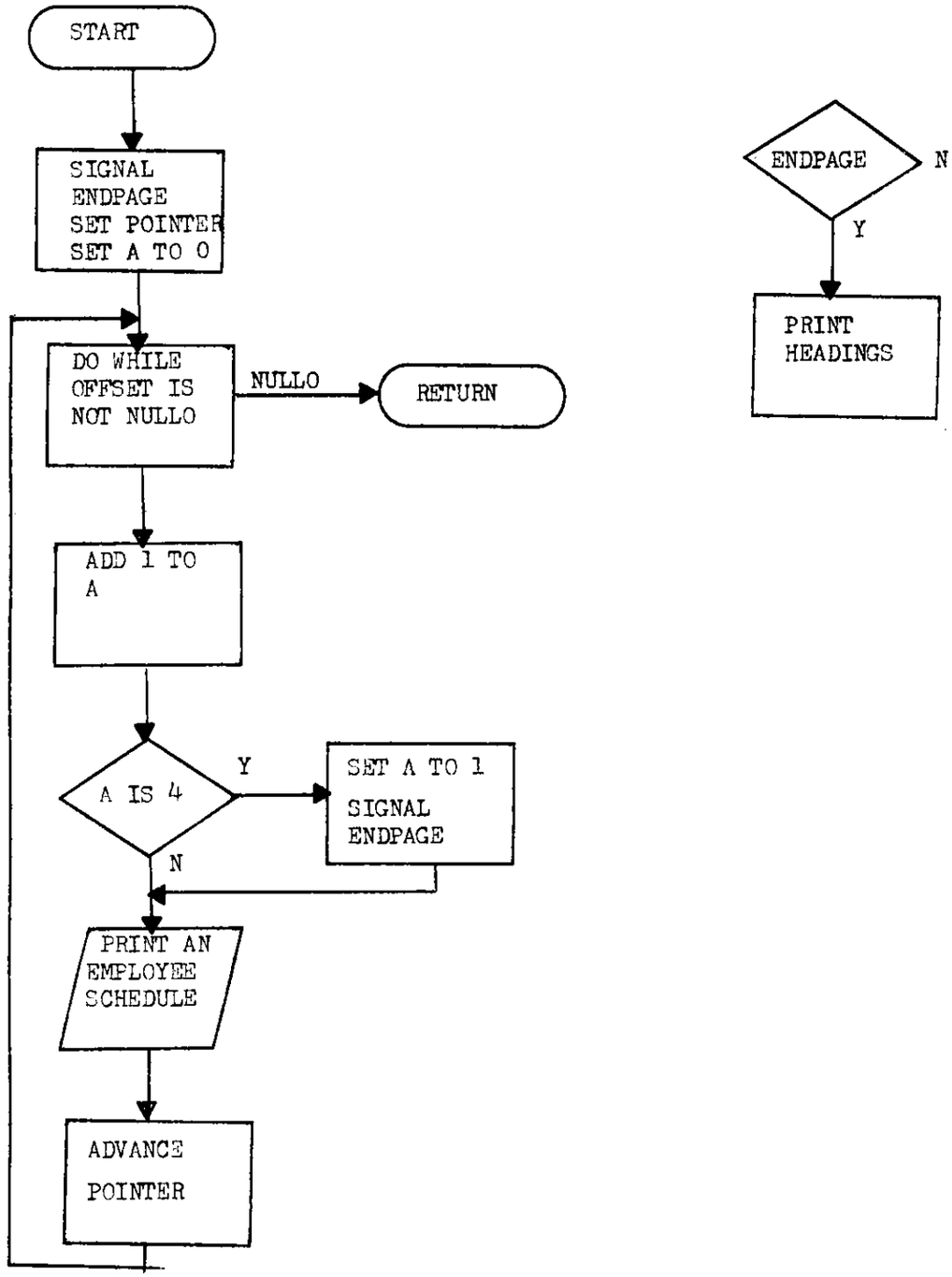

12B
ASSIGNMENT 1 IS SET TO ASSIGNMENT 2
12D
ASSIGN 2 ******
ASSIGN LOWEST PRIORITY EMPLOYEE NOT ASSIGNED
ZERO ARRAY SET ADDRESS ARRAY TO NULL
RETURN

PRINTER PROCEDURE

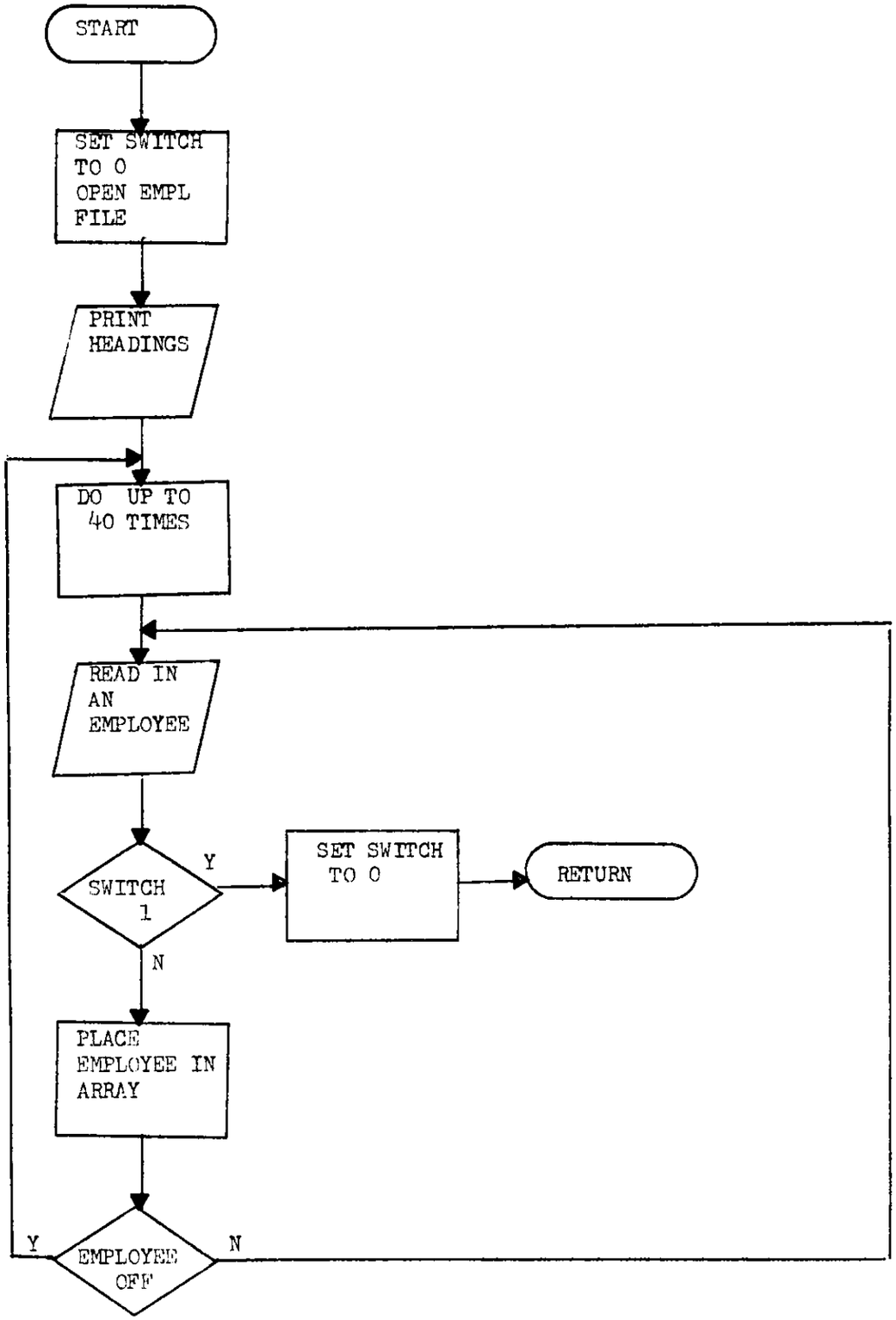




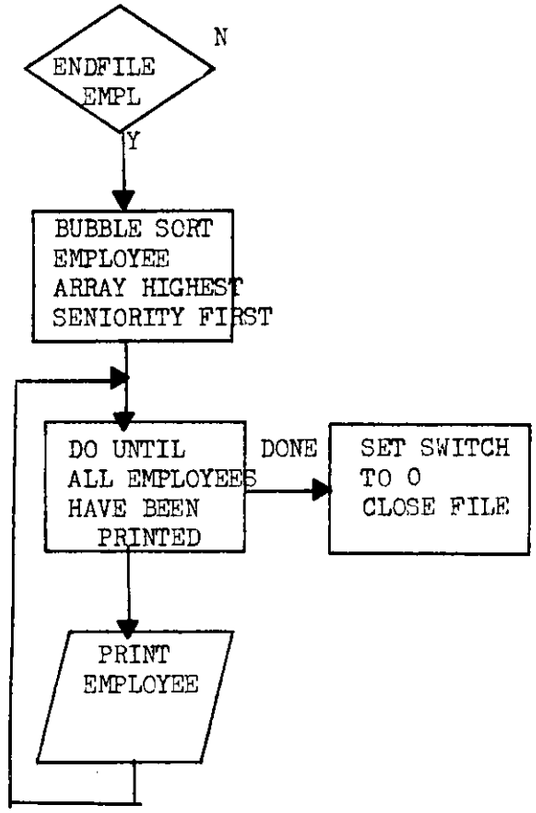
PRT_EMP PROCEDURE



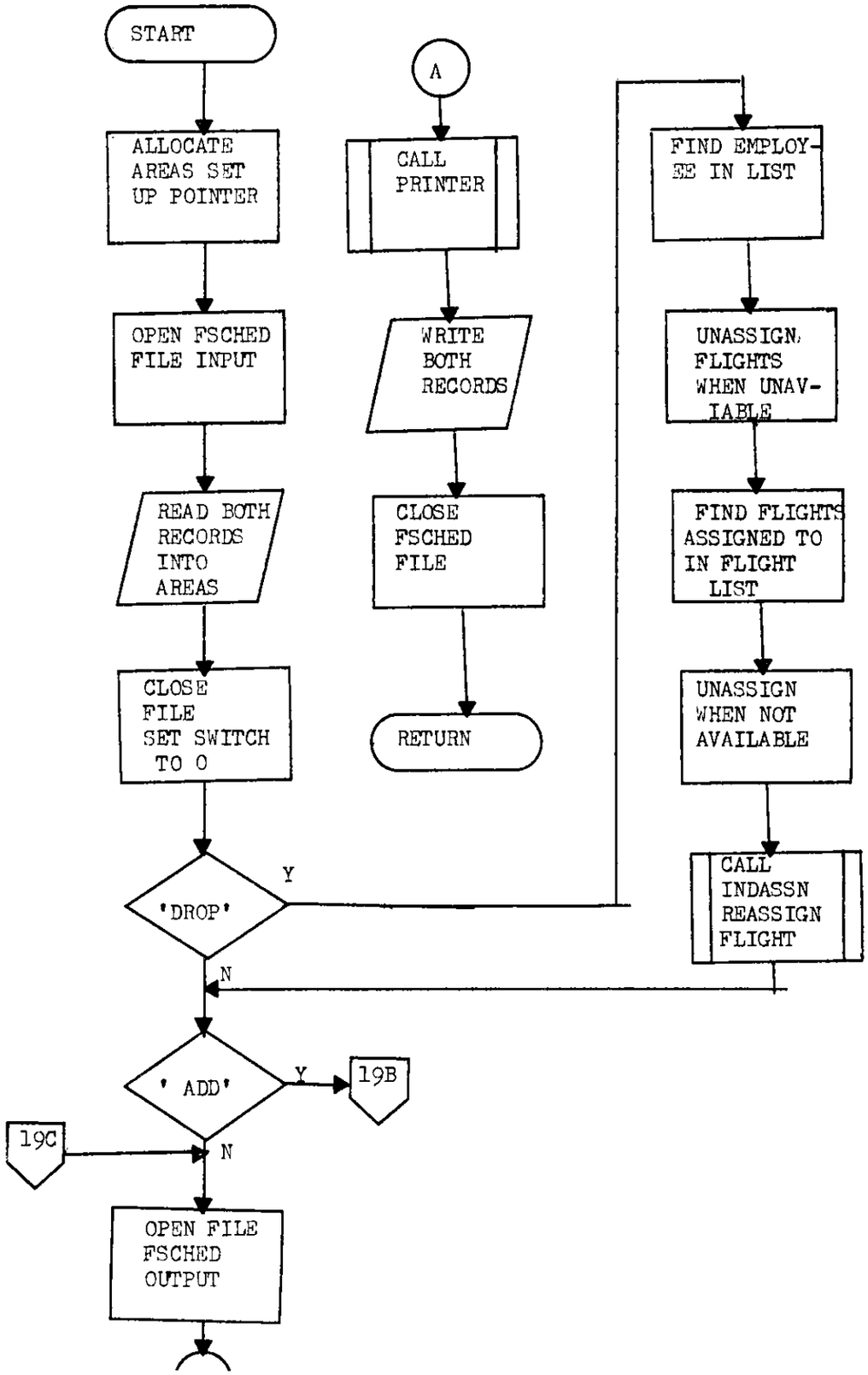
OT_LIST PROCEDURE

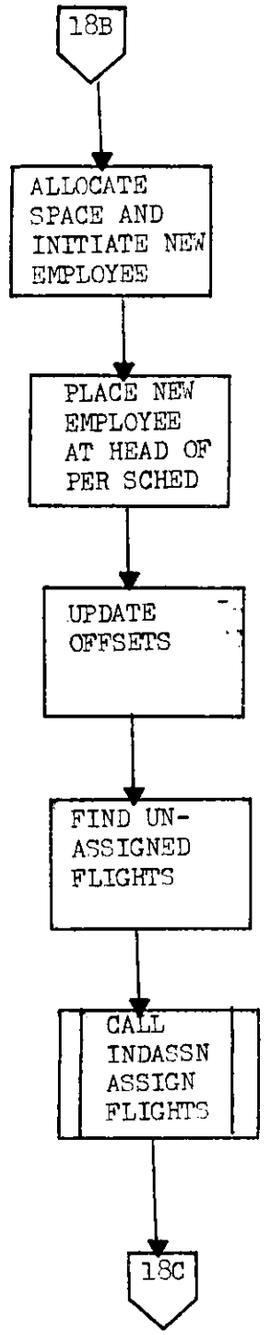


ENDFILE FOR OT_LIST PROCEDURE

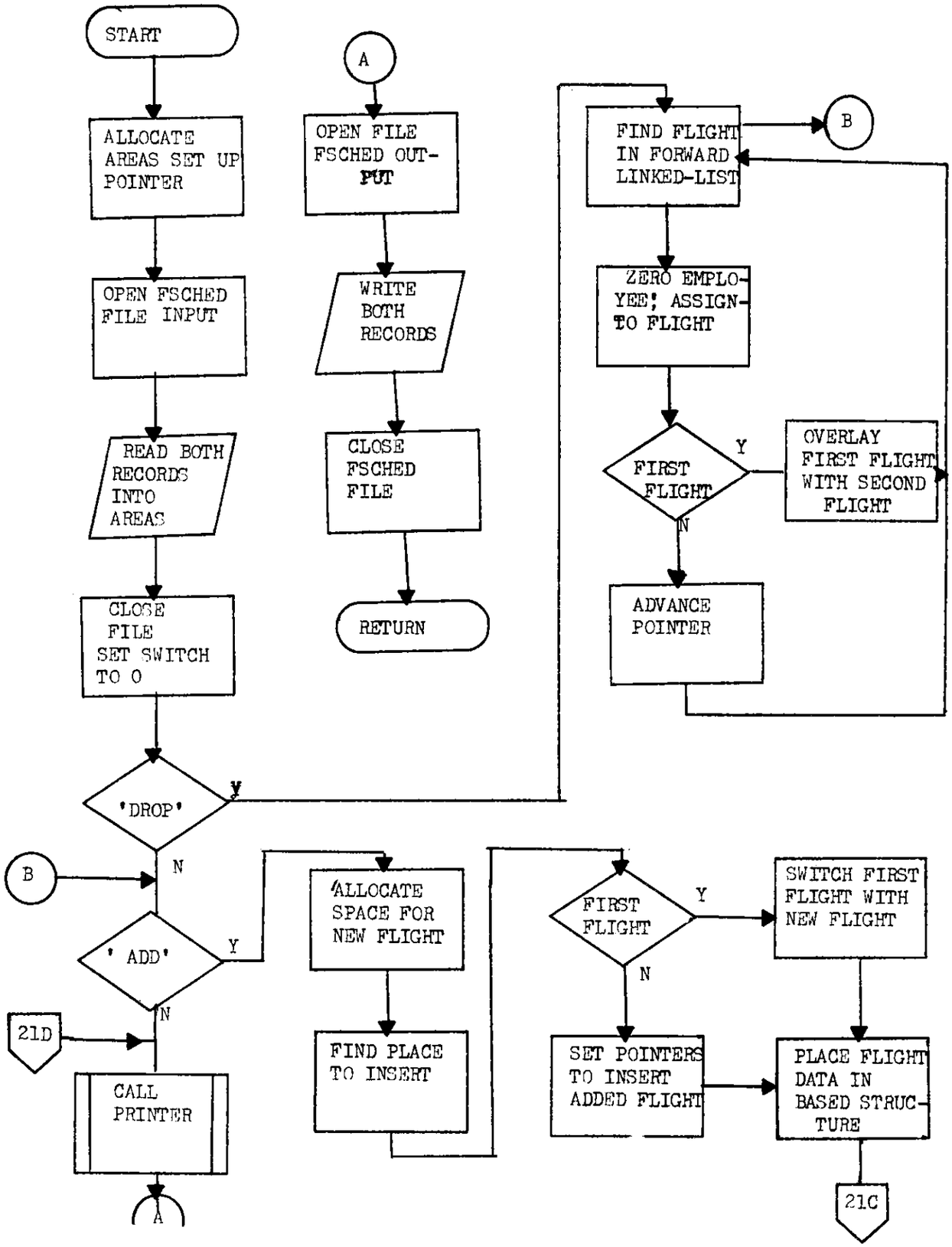


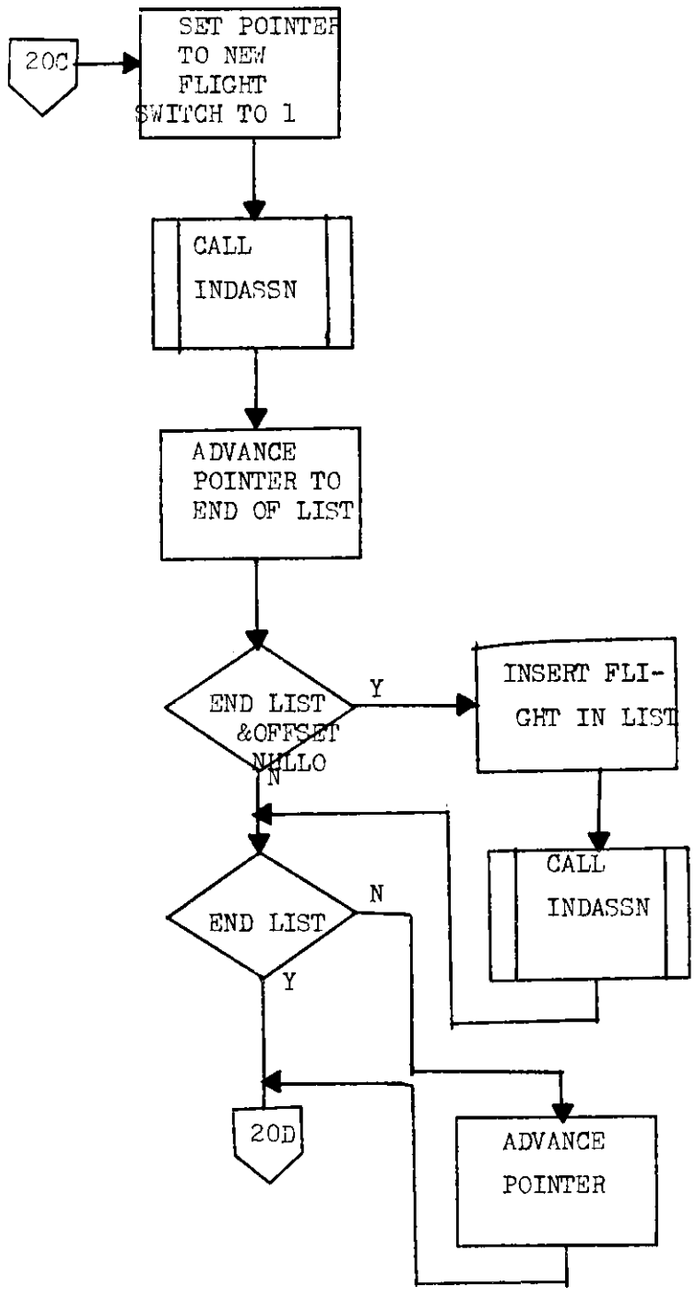
PER_RES PROCEDURE




18B
ALLOCATE SPACE AND INITIATE NEW EMPLOYEE
PLACE NEW EMPLOYEE AT HEAD OF PER SCHED
UPDATE OFFSETS
FIND UN-ASSIGNED FLIGHTS
CALL INDASSN ASSIGN FLIGHTS
18C

FLT_RSC PROCEDURE




20C
SET POINTER TO NEW FLIGHT SWITCH TO 1
CALL INDASSN
ADVANCE POINTER TO END OF LIST
END LIST &OFFSET NULLO
Y
N
INSERT FLIGHT IN LIST
CALL INDASSN
END LIST
N
Y
20D
ADVANCE POINTER